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EXPLOITATION AND POLLUTION IN ANTARCTICA:

A CASE HISTORY

by H.M. Platt

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EXPLOITATION AND POLLUTION IN ANTARCTICA : A CASE HISTORY

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ABSTRACT

The extent of the damage already done to the living resources of the Southern Ocean by successive campaigns of commercial exploitation is still essentially unknown. But some information on the scale of man's impact on a local level and as a result of the global build-up of certain anthropogenic pollutants is reported from a detailed biological and biochemical investigation of a small bay at South Georgia in the aftermath of intense land-based whaling activities. This and other examples from the past, difficulties over reaching international agreement to control current activities and the possibility of intensified exploitation do not augur well for the future. Urgent action is called for if a rational conservation policy is to be adopted.

INTRODUCTION

The vast cold desert of continental Antarctica is surrounded by one of the world's richest biological provinces - the Antarctic or Southern Ocean. The area is still considered by some as one of the few remaining outposts against the growing tide of environmental pollution and commercial exploitation. But this view is no longer tenable.

The Southern Ocean has already been damaged, although the full extent of this is still virtually unknown. Signs of the global build-up of pesticides have been detected in the fauna and environment (George and Frear, 1966; Sladen et al, 1966; Tatton and Ruzicka, 1967; Brewerton, 1969; Parker, 1972). Commercial activities in the last century brought Antarctic fur and elephant seals close to extinction (Matthews, 1931) and despite attempts at legislative control, a similar fate may still face the whale stocks. Large fleets of trawlers from the USSR, Poland and other nations are presently active

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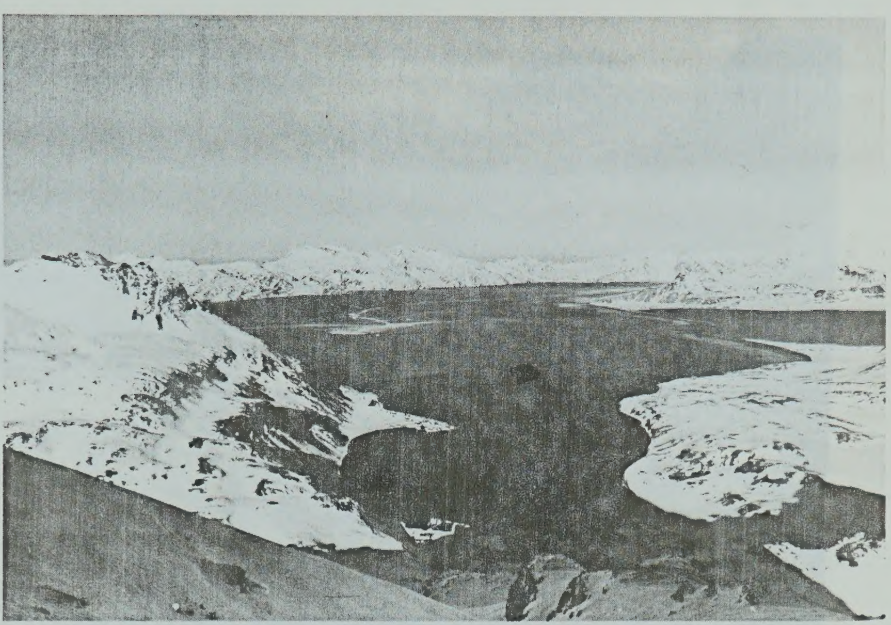

Figure 1. King Edward Cove and environs with the abandoned whaling station in the foreground.

in the region, apparently using pulse fishing techniques rather than attempting to achieve a sustainable yield (Everson, 1978; Bonner, pers. comm.) And voyages have already been made establishing a fishery based on the very foundation of the entire system - the Antarctic krill (El-Sayed, 1976; Everson, 1976; Everson, 1978).

Although the Antarctic Treaty, signed in 1959, contains measures concerned with the 'preservation and conservation of living resources' (Article IX), the provisions only apply south of the 60°S latitude and exclude the high seas (Article VI). Hence, many of the sub-Antarctic islands are not directly covered, although conservation legislation affords a degree of protection to their terrestrial flora and fauna. But no internationally agreed measures yet adequately protect the marine life around the islands despite the fact that these areas appear to be of paramount importance to the whole production cycle in the Southern Ocean (Anon., 1978).

One of the most important of these islands is South Georgia lying some 1600 km east of Cape Horn, within the Antarctic Convergence but north of the 60°S latitude and forming part of the Falkland Islands Dependancies. Turbulent seas promote the rich summer growth of phytoplankton on which the krill feed. Consequently, thousands of seals and millions of oceanic birds breed on South Georgia's shores and the surrounding ocean used to be an important feeding ground for large numbers of the world's baleen whales (Matthews, 1931).

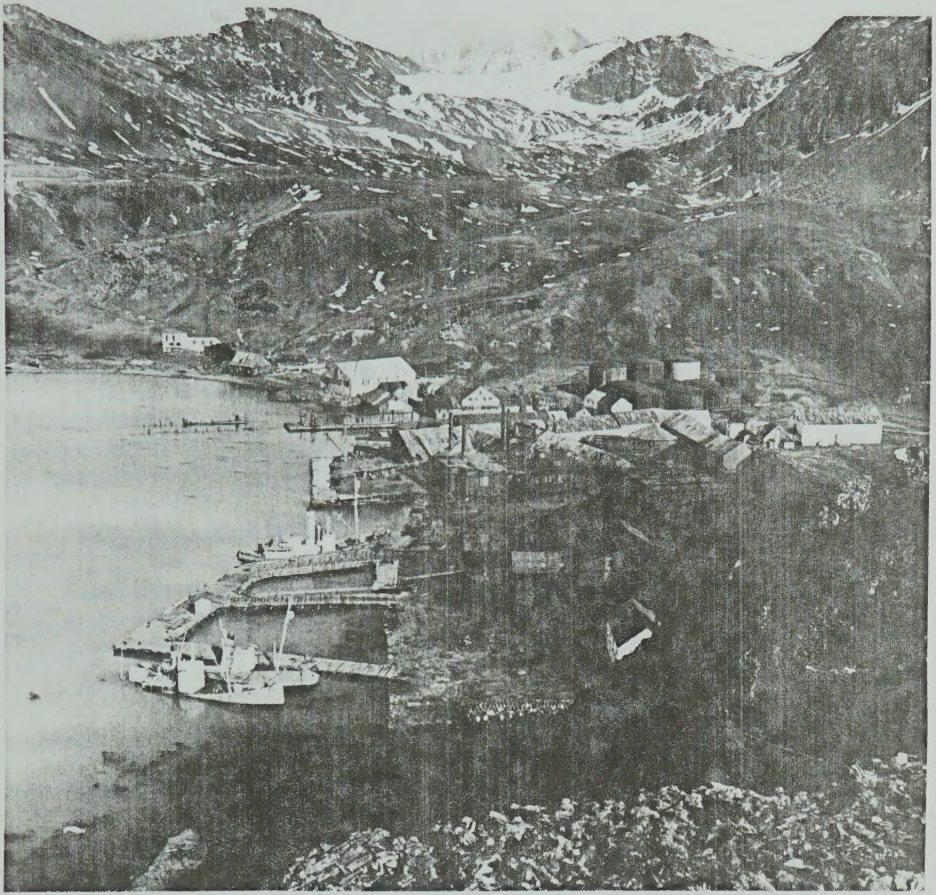

Figure 2. Grytviken, the decaying whaling station with sunken catchers and rusting oil storage tanks.

Commercially viable fish stocks are also to be found on the continental shelf and in the calmer waters of the fjords. Thus, once discovered, this annual congregation formed an irresistable attraction to man.

South Georgia was discovered only in 1775, but successions of sealing voyages rapidly reduced local seal populations so that by the latter part of the 19th century the sealing grounds were unprofitable to visit. However, with the development of fast manouverable steam catchers and the explosive harpoon gun enabling the relatively fast fin-whales to be taken, whaling expanded in the northern hemisphere. In 1904 the first of the great land-based whaling stations was founded in the Antarctic at Grytviken at the head of the sheltered bay now known as King Edward Cove (Fig. 1). Although now abandoned (Fig. 2), throughout the subsequent period of activity - until the 1964/5 season when overkilling finally made the operation unprofitable (Laws, 1979) - considerable

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quantities of organic material were dumped into the bay (Hardy, 1967). In addition, the Cove was contaminated by fossil fuels, especially through the practice of cleaning coal and later fuel oil from the tanks of transport ships prior to refilling with whale oil (Matthews, 1931).

It is against this recorded background of use by man, the known biological importance of such areas and the dearth of information on the effects of pollution in low-temperature polar systems, that a detailed study of the ecosystem was begun. This paper reviews that part of the work which highlights the magnitude and effect of localised pollution in King Edward Cove. The results are discussed in the context of the past, present and possible future interest in Antarctic resources in order to bring the story to the attention of a wider scientific audience.

SAMPLING AND ANALYSIS

King Edward Cove and the main sampling sites used in this work are shown in Fig. 3. Since the detailed methodology used has been reported elsewhere (see below) only a brief synopsis will be given here.

Sedimentation Sediment accumulation rates were investigated by collecting material in a series of glass jars set by divers at various distances above the sea bed (Platt, 1979a).

Macrobenthic survey Sampling (in 1973) was by diver-operated suction sampler and a Smith-McIntyre grab and the proceeds analysed for abundance, diversity and biomass (Platt, 1978, 1979b).

Hydrocarbon survey Several components of the Cove's ecosystem were sampled, including marine biota and sediments, freshwater sediment from remote lakes and terrestrial plants. Aquatic material was collected by divers who placed the samples in containers underwater to avoid later contamination. The deep-frozen material was returned to Torry Research Station, Aberdeen for subsequent analysis (Mackie et al, 1974, 1978).

RESULTS AND DISCUSSION

The benthic faunal assemblages at the 4-12 m deep stations appeared 'normal' : biomass ranged from 4-38 g ash-free dry weight/m^2. There was no evidence of a residual gradient (numerical or biomass) along the transect out from the main source of pollution (Grytviken) as might have been expected to have occurred during the period of industrial activity. It was finally concluded that in the eight years

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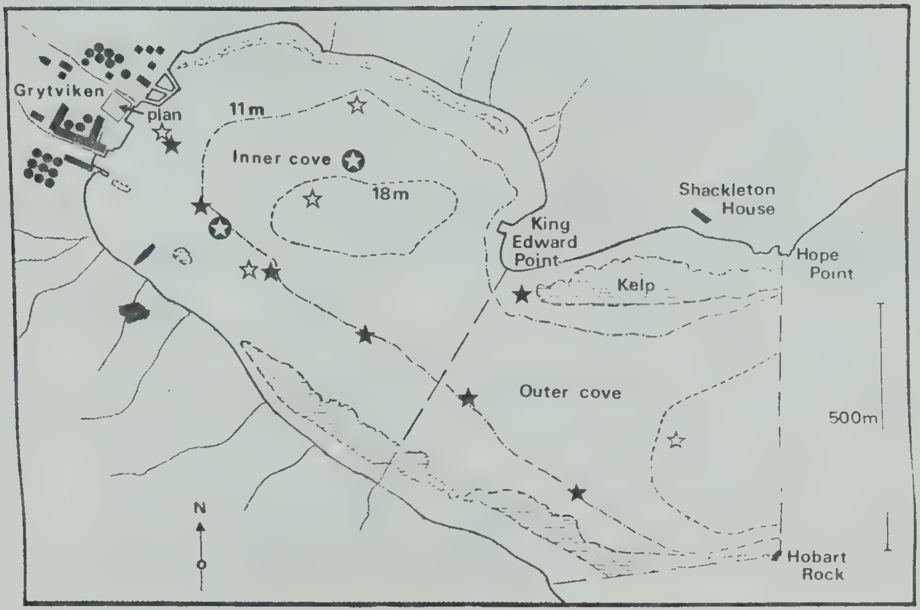

Figure 3. Map of King Edward Cove showing position of macrobenthos ★, hydrocarbon core ☆ and sedimentation ✪ sampling sites.

since whaling ceased, the system had recovered from pollution to a state indiscernable from what might be considered natural (Platt, 1978). However, there is no way of being absolutely sure that the biota today are the same as they were before 1904. Note that unpolluted control sites were difficult to find at South Georgia because most bays similar to King Edward Cove had whaling stations in them and there were certain logistic problems in surveying other possible sites.

The concentrations and distributions of aliphatic hydrocarbons in surface sediments, fish, benthos, krill, plankton and plants (i.e. the living system) showed no conclusive evidence of persistant contamination by petroleum or other wastes from the whaling station. Full details of the results will be reported elsewhere, but Fig. 4 summarises the main findings. Where meaningful comparisons are possible, the concentrations in these Antarctic samples appear to be consistent with those reported from the northern hemisphere (Mackie, _et al_, 1974, Whittle _et al,_ 1974, Whittle and Mackie, 1976). Given that the Cove has now returned to a virtually pristine condition, these findings are of interest since they suggest either the waters of the northern hemisphere (areas of acute spills excepted) are not abnormally enriched (at least not to concentrations easily discernable from the natural background of biogenic hydrocarbons) or that there

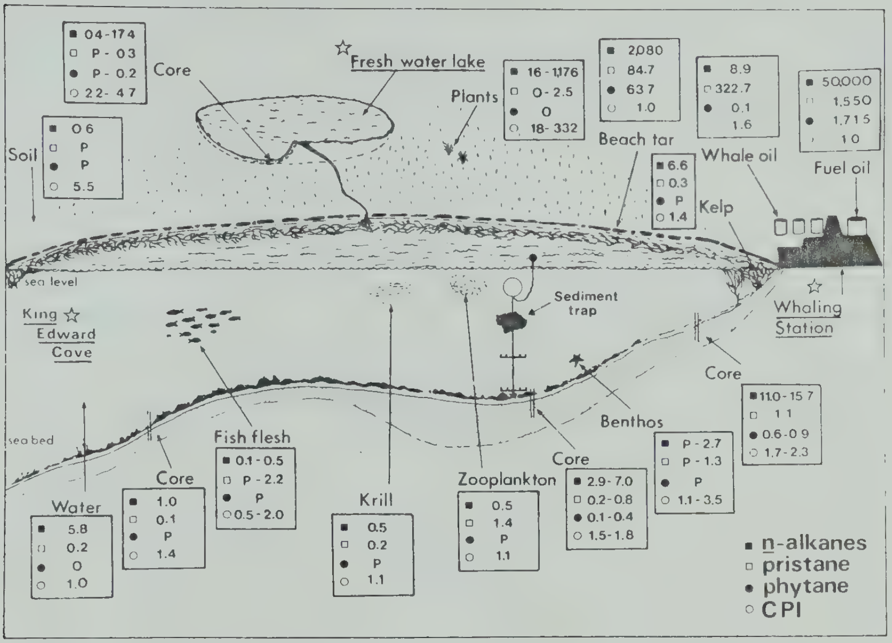

Figure 4. Aliphatic hydrocarbon levels in and around King Edward Cove as indicated by total n-alkanes (C_{15}-C_{33}), carbon preference index (CPI), pristane and phytane - see key. Data are ppm of wet weight for biota, ppm for dry weight for sediment and soil and µg/litre for water. P = present.

is a world-wide low-level background of abiogenic hydrocarbons which already extends into the Southern Ocean. This controversy arises because of the as yet unresolved difficulty in distinguishing unequivocally between biogenic and abiogenic hydrocarbons.

Evidence of the polluted state of King Edward Cove in the past comes from the detailed hydrocarbon distribution in deep cores taken from the centre of the bay. Some of these results, together with the levels found in South Georgian whale oil (to represent the organic input from the whaling factory) and fuel oil from abandoned storage tanks at Grytviken, are set out in Table 1.

The concentrations in the top few centimetres, representing sediment accumulated since about 1969, can be taken as relatively normal background levels. The aromatic components, such as the relative proportions of fluoranthene to pyrene and low dibenzthiophene levels, are consistant with combustion products being the major source (Laflamme and Hites, 1978). It is possible that activities at the nearby scientific station may make some minor contribution, but it is hardly likely to be significant relative to the huge input when the

TABLE 1

Hydrocarbons in selected sections of a 36 cm long sediment core, whale oil and fuel oil from South Georgia.

Hydrocarbon	Depth in sediment (cm)			Whale oil	Fuel oil
	0-3.5	6-16	28-34		
Total n-alkanes (µg/g)	2.5	4.8	6.5	8.9	4.9×10^{4}
n - C15 (% total alkanes)	3.1	1.9	13.7	59.6	8.1
n - C32 (% total alkanes)	3.9	7.7	3.2	1.5	0.9
Carbon preference index	1.8	1.4	1.6	1.6	1.0
Pristane (µg/g)	0.2	0.4	5.9	322.7	1550.9
Phytane (µg/g)	0.08	0.21	0.11	0.1	1715.4
Polycyclic aromatic hydrocarbons (ng/g)	99.6	319.7	500.7	86.2	3.3×10^{6}
Fluoranthene (ng/g)	10.4	43.0	87.2	0.6	0.0
Pyrene (ng/g)	9.2	59.1	67.1	1.8	4.6
Dibenzthiophene (ng/g)	0.3	3.4	3.3	2.0	9.6×10^{4}
Substituted naphthalene : naphthalene	4.6	5.4	3.0	2.5	15.9

whaling factory was in operation. This being so, the quantities in the surface layers would appear to be remarkeably high considering the remote location of South Georgia (Windsor and Hites, 1979), implying that natural or anthropogenic combustion products, coming either directly via the atmosphere or indirectly via the oceans, reach the Antarctic. The possibility of in situ poly-nuclear aromatic hydrocarbon (PAH) biosynthesis occurring is presently considered unlikely (Farrington et al, 1977; Hase and Hites, 1976).

It is immediately clear that quantities deeper in the core differ markedly, both quantitatively and qualitatively, from the surface values. The global production of PAH has been increasing over the past century (Hites et al, 1977) so that larger concentrations deeper in the core would not be expected. Yet both the aliphatic and aromatic values beneath the surface layer are higher. More detailed profiles than are given here show sudden increases in concentration in sections dated 1959-1964, coinciding exactly with the cessation of local industrial activity. Furthermore, other discontinuities seen throughout these profiles can only be explained as a result of local contamination since all other sources would be expected to give homogeneous or smooth distributions. The three main sources of local pollution are (i) organic whale refuse, (ii) fuel oil and (iii) combustion products from burning fossil fuels.

Some of the aliphatic hydrocarbons deep in the core (28-34 cm) indicate that the enrichment is due to whale refuse. For example, the amounts of n-pentadecane (n-C15) and pristane are extraordinarily high : both are major components of whale oil. These sediments must have been laid down early in the century, when only the blubber was used and the remaining carcases or 'skrotts' either left to rot or towed out to sea. After 1916, legislation required the factory to utilise the entire carcase and over the years, the process became steadily more efficient (Platt, 1978).

The high levels of polynuclear aromatic hydrocarbons (PAH)- many of which are toxic or mutagenic - at these deeper sediment levels are probably due to pyrolysis and residues from coal burning. If petroleum were a factor, an enhanced phytane level and lowered carbon preference index (CPI) would be expected. This latter parameter, the CPI, is a measure of the relative amounts of odd and even numbered carbon chain length n-alkanes. Fuel oil, for example, has equal amounts of odd and even numbered alkanes (a CPI of 1.0) whilst most biogenic sources show a varying degree of dominance by odd numbered alkanes (CPI greater than 1.0) - see Fig. 4.

The middle section of the core represents sediment accumulated between about 1940 and 1964: here the presence of petroleum can be detected. The n-alkane composition showed a reduced predominance of odd numbered carbon chains

which is indicative of the presence of oil. The CPI in the 8-10 cm cut was only 1.1, and the average value for the 6-16 cm zone was significantly lower than values normally found in coastal marine sediments. This is coupled with a somewhat enhanced phytane value. A further possible indicator is the slightly increased proportion of alkyl-substituted naphthalenes compared with the unsubstituted parent, another relationship typical of petroleum. The change-over from coal-burning to fuel-oil also appears to be reflected in the reduced total PAH value compared with deeper sediments.

The distribution of hydrocarbons in the sediment, then, accords very well with the known history of man's useage of the site. Furthermore, the vertical discontinuities suggest that diffusion and sediment reworking by benthic organisms may not have been important processes during this period. Although little is on record concerning the benthos of King Edward Cove either before or during the period of whaling activities, a consideration of the amounts of pollutants which entered the bay would suggest that the fauna must have been severely affected if not entirely eliminated. For example, dismembering some 900 whales per season, equivalent to almost 40,000 tonnes wet weight, must have caused considerable quantities of body fluids, stomach contents and other forms of organic particulate matter to have entered the Cove. In the early years, less than half of the possible extractable oil and no dry products were obtained from the animals, although this situation had improved considerably by the 1930's.

Once deposited on the sea bed, these contaminants may have continued to affect the overlying water through the process of resuspension. The sedimentation experiment showed that large quantities of the surface mud are returned to the water column throughout the year, but particularly during the summer months (Platt, 1979a). Almost 80% of the material collected in bottles near the sea bed was attributable to resuspension.

The experimental data further suggested that the net annual accumulation rate was in reasonably good agreement with the $2.8 \times 10^3 g/m^2$ (dry weight) figure deduced from organic profiles in sediment cores. From this, further tentative speculations on pollution rates can be made.

If the enhanced n-C15 and pristane levels in the 28-34 cm section (Table 1) were due to whale oil contamination alone and no biodegradation has since occurred, then an annual input per m^2 in the order of 400g (from the n-C15 data) and 50g (from the pristane data) of whale oil or its equivalent is suggested. Whatever the true form of the contaminating material, clearly massive organic inputs must have been involved to account for the concentrations still persisting - seriously overloading the benthic system.

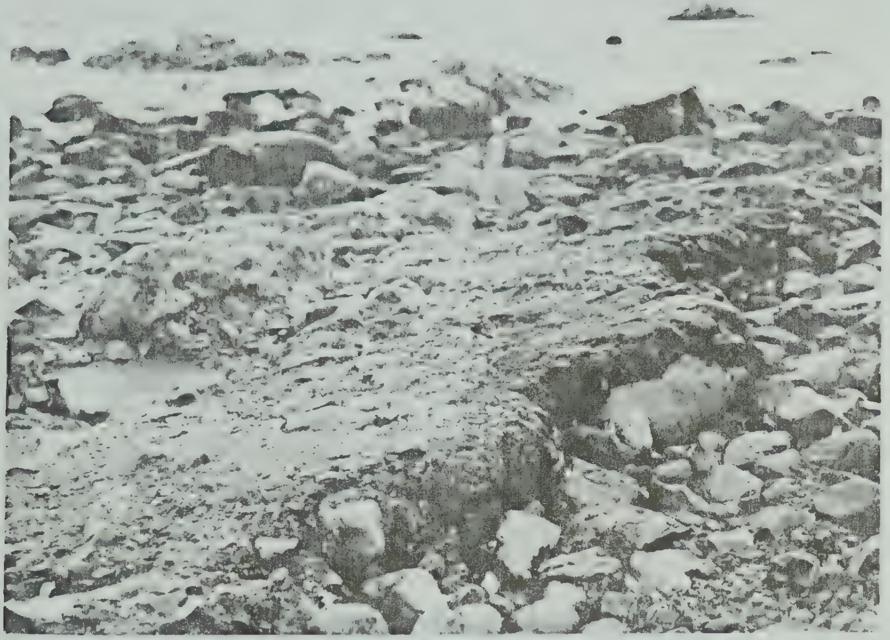

Figure 5. Asphalt-like beach tar residues on the southern shore of King Edward Cove.

In a similar way, the enhanced n-C32 level in the 6-16 cm section, if due solely to fuel oil contamination, suggests inputs of about 1.7g of fuel oil/m^2/year. Saturated alkanes are known to be more biochemically labile than other hydrocarbons (Shaw et al, 1977) so that the true input may well have been greater if biodegredation had occurred. Whatever the precise fuel oil input was, clearly a certain amount of petroleum reached the sea bed, including the toxic PAH (Blumer, 1972), with unknown short and long term effects. Further evidence of this contamination can still be seen along the shoreline, where there are thick patches of beach tar (Fig. 5).

CONCLUSIONS

The main conclusions that can be drawn from this survey are that:

(1) persistant chemical evidence testifies to the massive local pollution of King Edward Cove over a 60 year period
(2) although almost certainly seriously affected at the time, the marine biota appear to have recovered

(3) no evidence could be found that aliphatic hydrocarbon concentrations in the living environment of the Southern Ocean are significantly different from those found in other parts of the world

(4) airborne PAHs reach even remote parts of the world in relatively undiminished quantities.

Finally, the local pollution of King Edward Cove described here was the direct consequence of a large scale intensive fishery, i.e. whaling. Measures to control the pollution were absent, due partly to the remoteness of the area with no indigenous human population to press for some measure of accountability. Land based whaling has now ceased and the whaling stations left to decay, but any further exploitation of either living or mineral resources must be more carefully controlled, particularly if large scale *in situ* industrial plants are being contemplated (Laws, in press). It is to be hoped that measures planned for the Convention for the Conservation of Antarctic Marine Living Resources (Everson, 1978) will provide such safeguards to protect the unique life of the Southern Ocean.

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